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The Larval Elateridae of Eastern Spruce Forests and Their Role in the Natural Control of *Gilpinia hercyniae* (Htg.) (Hymenoptera: Diprionidae)[1]

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Introduction

One of the objects of the investigations on the European spruce sawfly, *Gilpinia hercyniae* (Htg.), in Eastern Canada was to discover and evaluate the factors of natural control affecting this introduced species in its new environment. Small mammal predators were found to be the most important factor affecting the sawfly cocoons, which were spun in the moss or litter of the forest floor (4, 5). These predators chewed large openings in the cocoons and pulled out the contents. Cocoons were also found with smaller openings made by the entry of insect predators, and occasionally such a cocoon was found with a larva of the family Elateridae partly inside (Fig. 1).

In 1939 it became a part-time project of the writer to study the species of elaterid larvae occurring in the forest floor of coniferous stands, with particular reference to the determination of their role in the natural control of the sawfly. The intensive phase of the field work was carried out on two plots in central New Brunswick and one in the Gaspé Peninsula, Quebec. They were permanent plots, selected to represent certain typical conditions, and had been established earlier for cocoon population sampling and other intensive studies on the sawfly. More extensive collections of larval Elateridae and of sawfly cocoons were made at other points in New Brunswick. Most of the field work was carried out between 1939 and 1946, and the rearing of larvae, which was conducted first at Fredericton and later at the Green River Laboratory, occupied approximately the same period.

Rearing of Elaterid Larvae

The study was purely ecological in scope and problems of larval morphology were avoided as much as possible. When the work was started, however, it was found that only a small proportion of the larvae of this family had been described, and that previous collecting in the forests of this region had been very limited. It was therefore necessary to rear as many species as possible to the adult stage, and this was combined with the study of food habits. Each larva was reared in an individual petri dish or salve tin, which was filled with the same type of leaf litter or moss from which the larva was collected. These containers were numbered consecutively so that, for any one larva, the same number appeared on the collection data, the rearing notes, and the food habits data. If the larva was reared successfully, the same number was also used for the preserved larval exuviae and for the pinned adult; otherwise it was used for the dead larva or pupa. On the basis of observed differences in larval morphology, collected larvae were separated into twenty types which were considered by the writer to represent different species. A type number, or species number, was entered in the rearing notes but was never accepted as final until a more detailed examination had been made, based on the larval exuviae or on the dead larva.

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Of the recognized types, only eight were reared successfully to the adult stage. In 1943 samples of all types were sent to Dr. Robert Glen of the Dominion Entomological Laboratory, Saskatoon, who was then engaged in a detailed morphological study of all available identified *Ctenicera* larvae of the world. Fortunately, he was able to identify all but a few of the specimens and exuviae submitted. In his recent monograph on the tribe Lepturoidini (3), reference is made to the New Brunswick and Gaspé material and many of the species herein mentioned are described in detail.

The following list includes notes on identification, especially in those cases where the specific determinations are still lacking or doubtful:—

Ctenicera triundulata (Randall): Reared by writer and by others (3).

Ctenicera nitidula (LeConte): Reared by writer and by others.

Ctenicera resplendens aeraria (Randall): Reared by others.

Ctenicera sp. (No. 11): Never reared to maturity. The number is the type number used in the rearings. Glen (2) suggests that either No. 11 or No. 20 might well be the larva of *C. spinosa* (LeConte), since the larvae of this species and its relatives are unknown. A comparison of the relative frequencies of occurrence of larvae (Table I) and adults (Table II) supports the possibility that No. 11 may be *C. spinosa.*

Ctenicera rufopleuralis (Fall) (?): Never reared to maturity. Glen (3) reports that the larvae submitted bear a strong resemblance to those of *nitidula* (LeConte) and regards them as either *rufopleuralis* (Fall) or *arata* (LeConte), the larvae of these two species being unknown. Larvae of this type were collected rather commonly in New Brunswick (Table I). Adults of *arata* were fairly common but those of *rufopleuralis* were relatively uncommon (Table II). This suggests that the larvae were actually *arata*, or that characters for distinguishing the two species in the larval stage were not apparent. However, in accordance with Glen (3), the name *rufopleuralis* (?) is used throughout the present paper.

Ctenicera propola propola (LeConte): Reared by others.

Ctenicera appropinquans (Randall) (?): Never reared to maturity. Glen states (2): "As far as I am aware *appropinquans* is the only species with a larva of this type that inhabits Eastern Canada. The larva of *appropinquans* has never been reared to maturity, but I know the larvae of several closely allied species and I can see no other possibility than *appropinquans* for your eastern form."

Ctenicera appressa (Randall): Reared by M. L. Prebble from Gaspé material.

Ctenicera hieroglyphica (Say): Reared by others.

Ctenicera sp. (No. 9): Never reared to maturity. Larvae of this type bear a strong superficial resemblance to those of *C. cylindriformis* (Herbst) but Glen (2) doubts whether they are this species, or are even closely related.

Ctenicera mediana (Germar): Reared by writer.

Ctenicera sp. (No. 20): Never reared to maturity. See remarks above under *Ctenicera* sp. (No. 11).

Agriotes limosus (LeConte): Reared by writer and by others. There are several other species of *Agriotes* in New Brunswick (Table II), of which the larvae are unknown. If these larvae are very similar morphologically, it is possible that other species besides *limosus* were included in the rearings.

Dalopius vagus Brown (?): Reared by writer. A single specimen reached the adult stage and this was a female which was identified by W. J. Brown as *Dalopius* sp. probably *vagus* Brown.

Ampedus spp.: Not reared to maturity. At least two species and possibly more, were collected and reared but no specimens reached the adult stage.

Athous rufifrons (Randall): Reared by writer and by others.

Sericus honestus (Randall): Reared by writer.

Eanus decoratus (Mannerheim): Reared by writer and by others from Gaspé-collected material. A larva collected in central New Brunswick (Table I) and thought to be this species differs from the Gaspé larvae by having a slight protuberance on the postero-lateral aspect of the urogomphus.

FIG. 1. Larva of *Ctenicera triundulata* (Randall) feeding inside cocoon of *Gilpinia hercyniae* (Hartig). Natural length of cocoon 8 mm.

The adults that were reared were identified by W. J. Brown of the Division of Entomology, Ottawa. All insect material accumulated during the study, including the adults, larvae and exuviae from rearings, as well as miscellaneous collections of larvae, are stored in the Canadian National Collection, the wire-worm section of which is at present in the Dominion Entomological Laboratory, Saskatoon, Saskatchewan.

Key to Species

In 1943 Dr. Glen prepared for the writer a provisional key for the identification of the larvae submitted. This key was found extremely useful, and as no new species were taken after 1943, it is complete for all species collected in

the larval stage during the investigation. Although the intensive collections were made on two areas in central New Brunswick (Acadia Forest Experiment Station in Sunbury Co. and Young's Brook in York Co.), general collections were made from such widely separated parts of the Province as the headwaters of the Green River in Restigouche Co., Lepreau in Charlotte Co., and at several points along the Miramichi River in Northumberland Co. In all, some 1,700 specimens were collected. It is considered, therefore, that the key is fairly complete for New Brunswick, although additional species of more rare occurrence can doubtless be added if future work is done. For Gaspé, where the collecting was limited to one plot (Brandy Brook on Upper Cascapedia River), it is without doubt incomplete.

The key is reproduced below, with the permission of Dr. Glen. It will be appreciated, of course, that it is applicable only to larvae collected from a restricted habitat, which may be defined as the layer of moss and decomposing litter in the spruce-fir forest type.

1. Ninth abdominal segment with a median posterior notch 2
   Ninth abdominal segment without a median notch 15
2. Urogomphi ("cerci") simple .... *Eanus decoratus* (Mann.)
   Urogomphi bifid (one or both prongs may be very small) 3
3. Caudal notch small and nearly closed posteriorly 4
   Caudal notch large and wide posteriorly 7
4. Outer prong of urogomphus several times as long as inner prong; abdominal mediotergites bearing conspicuous transverse rugae *Athous rufifrons* (Rand.)
   Urogomphal prongs subequal in length or outer prongs only slightly longer; abdominal mediotergites without conspicuous transverse rugae 5
5. Nasale unidentate; short transverse impression on abdominal mediotergites .... *Ctenicera appressa* (Rand.)
   Nasale tridentate at tip; long transverse impression on abdominal meriotergites 6
6. Inner prong of urogomphus with prominent posterior tubercle; eyes poorly defined .... *Ctenicera* sp. (No. 9)
   Inner prong of urogomphus without prominent tubercle; eyes well defined .... *Ctenicera resplendens aeraria* (Rand.)
7. Nasale tridentate at tip 8
   Nasale unidentate 10
8. Outer prong of urogomphus about twice as large as inner prong; second segment of antenna bearing one sensory appendix 9
   Urogomphal prongs subequal or inner prong slightly longer; second segment of antenna with more than one sensory appendix (usually about 5) .... *Ctenicera mediana* (Germ.)
9. Nasale and adjoining area of frons deeply sunken; nasale narrow, tip divided into three narrow forward-projecting denticles .... *Ctenicera* sp., *rufopleuralis* (Fall) or *arata* (Lec.)
   Nasale and adjoining area of frons only moderately depressed; nasale broad, tip tridentate, median denticle largest, lateral denticles projecting anterolaterad .... *Ctenicera nitidula* (Lec.)
10. Urogomphal prongs subequal in length 11
    Outer prong distinctly longer than inner prong 12
11. Outer prong of urogomphus blunt; abdominal mediotergites with long transverse impression .... *Ctenicera triundulata* (Rand.)
    Outer prong of urogomphus sharp (when not eroded); abdominal mediotergites with short impression .... *Ctenicera appropinquans* (Rand.)

12. Abdominal mediotergites with transverse impression extending to mid-dorsal suture .... *Ctenicera* sp. (No. 20)
    Abdominal mediotergites with shorter impressions 13
13. Outer prong of urogomphus at least three times as long as inner prong .... *Ctenicera* sp. (No. 11)
    Outer prong of urogomphus not more than twice as long as inner prong 14
14. Urogomphi long and slender; inner prong of urogomphus about twice as long as width at base; larva may exceed 16 mm. in length .... *Ctenicera hieroglyphica* (Say)
    Urogomphi short; inner prong of urogomphus less than twice as long as wide; larva not exceeding 16 mm. in length *Ctenicera propola propola* (Lec.)
15. Tip of ninth abdominal segment smoothly rounded; mandibles with preapical teeth in addition to the main tooth (retinaculum) which is located near the middle of the mandible .... *Sericus honestus* (Rand.)
    Tip of ninth abdominal segment pointed either bluntly or sharply; mandibles without preapical teeth 16
16. With striate impressions and conspicuous pits on abdominal mediotergites; nasale unidentate .... *Ampedus* spp.
    Without striate impressions and conspicuous pits; nasale tridentate at tip 17
17. Ninth abdominal segment with sharp tip and two or three whorls of small preapical setiferous tubercles .... *Dalopius* spp.
    Ninth abdominal segment with blunt tip and without preapical tubercles .... *Agriotes limosus* (Lec.)

Composition of Larval Populations

The percentage composition by species for all larvae collected and identified is listed separately for the principal plots, and as a mean for New Brunswick (Table I). These data were first listed separately by years, but as no significant

TABLE I.

Percentage Composition by Species for Collections of Larval Elateridae from Various Plots in New Brunswick and Gaspé, based on All Specimens collected between 1940 and 1945.

Species	Acadia Station N.B.	Young's Brook N.B.	Other Plots N.B.	Mean N.B.	Brandy Brook Gaspé
Ctenicera triundulata	43.6	21.2	24.7	31.4	2.1
" *nitidula*	24.3	11.6	31.3	23.3	2.1
" *resplendens aeraria*	1.4	16.4	11.0	8.6	0.0
" sp. (No. 11)	0.5	14.4	9.4	7.1	0.0
" *rufopleuralis* (?)	5.5	1.4	6.0	4.6	0.0
" *propola propola*	3.7	8.2	0.6	3.8	0.0
" *appropinquans* (?)	1.8	2.7	6.6	3.7	0.0
" *appressa*	0.9	7.6	1.6	2.9	0.0
" *hieroglyphica*	1.8	0.7	0.0	0.9	0.0
" sp. (No. 9)	0.0	0.0	2.7	0.9	0.0
" *mediana*	0.9	0.0	1.1	0.7	0.0
" sp. (No. 20)	0.0	0.7	1.1	0.6	0.0
Agriotes limosus	8.2	4.1	1.7	4.9	0.0
Dalopius vagus (?)	0.9	10.3	0.5	3.3	0.0
Ampedus spp.	6.0	0.0	1.1	2.7	0.0
Athous rufifrons	0.0	0.7	0.0	0.2	0.0
Sericus honestus	0.0	0.0	0.6	0.2	0.0
Eanus decoratus	0.5(?)	0.0	0.0	0.2	95.8
	100.0	100.0	100.0	100.0	100.0

changes in species composition were apparent, the results have been grouped for the whole collection period. Brief descriptions of the plots follow:—

Acadia Station, N.B.—Stand 80 per cent black spruce, *Picea mariana* (Mill.) B.S.P., with a scattering of white spruce, *Picea glauca* (Moench) Voss, balsam fir, *Abies balsamea* (L.) Mill., and intolerant hardwoods. Age 60 years. Ground level, but fairly well drained. Litter layer 1-2 inches thick, in many places freely exposed and in others covered by a thin layer of moss (*Calliergon*, *Hypnum*). All collections made under black spruce.

Young's Brook, N.B.—Stand 80 per cent white spruce with the remainder largely balsam fir. Age 80 years. Poorly drained in some places. Litter 1-2 inches deep, exposed in a few places and in others covered by a layer of either *Calliergon* and *Hypnum* mosses, or of *Spagnum* and *Polytrichum*. All collections made under white spruce.

Other plots, N.B.—Largely white spruce and more similar to Young's Brook than to Acadia Station except that on some plots, such as the one at Dunbar Brook, the litter layer was very shallow.

Brandy Brook, Gaspé.—Stand 90 per cent black spruce with a scattering of balsam fir (*A. balsamea* var. *phanerolepis* Fern.) and intolerant hardwood. Age 200 years. Good drainage on steep slope. Ground cover a uniform layer of moss (*Sphagnum*, *Calliergon*), 6-12 inches in depth. All samples taken under black spruce.

The larval populations on the New Brunswick plots show a considerable degree of similarity in species composition. Nearly 90 per cent of all the larvae belong to the genus *Ctenicera*, and 55 per cent to the two species *C. triundulata* and *C. nitidula*. Six other species of this genus occur rather frequently, as do the genera *Agriotes*, *Dalopius*, and *Ampedus*; all the other species are relatively uncommon. The Brandy Brook population, on the other hand, consists almost entirely of *Eanus decoratus*, only two other species being recorded. This is attributable, in all probability, to the difference in the nature of the forest floor rather than the difference in locality. Larvae of *E. decoratus* seem to be limited in occurrence to deep moss layers; the only specimens recorded in New Brunswick were taken from a small *Sphagnum* bog at Acadia Station. For this reason it is doubtful whether the composition of the Brandy Brook population is typical of the whole Gaspé.

Composition of Adult Populations

Information on the relative abundance of the species of adult Elateridae is available from records of the Forest Insect Survey at the Fredericton Laboratory. During the sawfly outbreak collections of insects were made throughout New Brunswick by the Survey and its co-operators. Each sample consisted of the insects dislodged onto a 7 by 9 foot canvas sheet by 'beating' the foliage of a young tree with a 10-foot pole. All species of insects were collected from the sheet and sent to the Laboratory for identification, elaterid adults being included until 1945. It is clear that the presence of an elaterid adult on spruce foliage constitutes a 'perching' record rather than a host record. The information is useful, however, in indicating the relative abundance of different species.

In summarizing these data, the species are listed for each genus in the order of decreasing abundance (Table II). The number of species of adults recorded was about twice as great as the number of larval species collected from the litter. Probably this results partly from the more extensive nature of the adult collections and partly from the fact that many of these collections were taken along the borders of fields and roads where they would include species which matured in cultivated land rather than in spruce litter. Nevertheless, the relative

TABLE II.

Relative Populations of Adult Elateridae collected from Foliage of Spruce and Fir in New Brunswick between 1938 and 1944. Sampling was carried out by spreading a 7′ x 9′ Canvas under each Tree and 'Beating' the Foliage with a 10-foot Pole.

Species	No. of samples in which species occurred	Total No. of specimens
Ctenicera nitidula (Lec.)	331	623
" *triundulata* (Rand.)	268	589
" *propola propola* (Lec.)	107	161
" *appropinquans* (Rand.)	92	120
" *arata* (Lec.)	61	74
" *mediana* (Germ.)	33	65
" *spinosa* (Lec.)	47	61
" *resplendens aeraria* (Rand.)	47	58
" *hieroglyphica* (Say)	19	30
" *fulvipes* (Rand.)	6	16
" *falsifica* (Lec.)	11	12
" *cruciata pulchra* (Lec.)	7	8
" *rufopleuralis* (Fall)	5	5
" *insidiosa* (Lec.)	4	4
" *kendalli* (Kby.)	2	2
" *cylindriformis* (Hbst.)	1	1
" *splendens* (Zieg.)	1	1
Agriotes limosus (Lec.)	140	246
" *collaris* (Lec.)	9	11
" *fucosus* (Lec.)	9	10
" *stabilis* (Lec.)	2	2
Limonius aeger Lec.	42	59
Dalopius vagus Br.	3	3
" spp.	21	31
Ampedus melsheimeri (Leng.)	9	11
" *apicatus* (Say)	5	5
" *pullus* (Germ.)	4	4
" *nigrocollis* (Hbst.)	1	1
" spp.	25	28
Melanotus spp.	20	28
Athous rufifrons (Rand.)	1	1
Sericus brunneus (L.)	11	11
Eanus estriatus (Lec.)	2	4
" *decoratus* (Mann.)	1	1
Lacon brevicornis (Lec.)	4	4
Cardiophorus gagates Er.	1	2
" spp.	4	6
Oxygonus montanus Schffr.	2	2
Drasterius debilis Lec.	1	1
Hemicrepidius memnonius (Hbst.)	1	1
Denticollis denticornis (Kby.)	1	1
Agriotella bigeminata (Rand.)	1	2
Adelocera brevicornis (Lec.)	1	1
Megapenthes stigmosus (Lec.)	1	1

abundance of the more common species of adults (Table II) agrees very well with that of the larvae (Table I). *Ctenicera triundulata* and *C. nitidula* were again the most prevalent species, although their order is reversed. *Ctenicera*, *Agriotes*, *Dalopius*, and *Ampedus* were again the important genera. *Limonius* and *Melanotus* were taken rather commonly in the adult stage and are known to be pests of economic importance in cultivated land (1). This explains their absence from the larval collections and tends to support the preceding remarks. In comparing Table I with Table II, the notes concerning the identity of *Ctenicera rufopleuralis* (?) and *Ctenicera* sp. (No. 11) should be consulted (above).

Density of Larval Populations

Population studies to find the number of wireworms per unit area of the forest floor were carried out in conjunction with cocoon population studies, and the sampling methods were therefore identical with those described by Prebble (6) for the European spruce sawfly. Briefly, fifty co-dominant spruce trees scattered over an area of several acres on each plot were selected and marked. Four quadrats, each measuring 1 foot square, were distributed at random under the crown of each tree. The moss and litter were removed from each quadrat and examined carefully by one worker, then checked by a different worker. The same trees were used in successive years but fresh quadrats were always selected. On the Young's Brook plot, one quadrat of 4 square feet per tree was used until 1946 in place of four quadrats, but in all cases the total sampling area per plot was 200 square feet. All sampling was carried out in May and June. The number of wireworms was recorded separately for each quadrat. Individual species were not recorded by quadrats but all specimens were saved and species composition was determined for the plot as a whole.

Small larvae in the early instars are similar in colour, shape, and size to dead spruce needles in the litter, and are therefore easily missed. On the average, 33.5 per cent of the larvae collected were missed in the first examination. It is probable that a small percentage was missed in the second examination. Furthermore, the sampling of elaterid populations was in all cases incidental to the sampling of cocoon populations, and when a worker is concentrated upon finding one object it is easy to miss another object which is different in colour and shape. For these reasons the population figures are probably conservative. In view of these factors, it was considered that the figures did not merit the detailed statistical treatment which was accorded to the cocoon sampling. Analysis was therefore limited to finding the mean population per square foot on each plot.

Populations of both larval Elateridae and living sawfly cocoons are presented in Table III. The data on wireworm populations were assembled and analysed by the writer. The data on cocoon populations at Acadia Station and Brandy Brook were assembled and analysed for certain years when the writer was responsible for the work on these plots, and in other cases they have been taken from Prebble (6) and from Annual Reports of the Fredericton Laboratory.

Table III shows the independence of sawfly and wireworm populations. The sawfly population in New Brunswick started to decline in 1940 and reached a very low level by 1942. The wireworm population fluctuated considerably from year to year but showed no consistent decrease as sawfly cocoons disappeared. Furthermore, wireworm population was significantly higher at Acadia Station, whereas the sawfly was much more abundant at Young's Brook. Either sawfly cocoons are not an important source of food for larval Elateridae, or else food is not a factor limiting wireworm populations.

The consistent differences in wireworm populations from plot to plot cannot be fully explained because habitat preferences were not studied. There is some tendency, however, for the highest populations to be associated with the greatest depth of moss and litter. This is clear when Table III is compared with the plot descriptions. On a plot at Dunbar Brook, N.B., not listed in the table, the litter layer did not exceed 0.5 inches in most places; here the wireworm population per square foot was as follows: 1940—0.09, 1941—0.06, 1942—0.05.

Food Habits

All larvae were reared individually since this not only gave greater control in feeding experiments but also eliminated cannibalism, which occurs commonly when larvae are reared together. Sawfly cocoons were provided in nearly all

TABLE III.

Population per Square Foot of Larval Elateridae and Living Sawfly Cocoons on Three Permanent Plots, based on Samples of 200 Square Feet per Plot. (A dash signifies no data.)

Year	Acadia Station		Young's Brook		Brandy Brook	
	Larvae	Cocoons	Larvae	Cocoons	Larvae	Cocoons
1937	—	—	—	7.90	—	8.92
1938	—	2.30	—	16.67	—	13.90
1939	0.63	5.24	0.28	23.95	1.00	8.59
1940	0.80	1.36	0.26	7.15	1.08	5.32
1941	0.40	0.22	0.33	0.27	—	6.04
1942	0.54	0.06	0.19	0.00	—	—
1943	0.57	0.05	0.14	0.01	—	—
1944	0.20	0.05	—	0.01	—	—
1945	0.38	0.23	—	0.01	—	—
1946	0.30	0.02	0.19	0.05	—	—
1947	—	0.00	0.33	0.02	—	—
1948	—	—	0.20	0.00	—	—
Mean	0.47		0.24		1.04	

instances. Sometimes both living and dead cocoons were used, arranged in such a way that it was possible to determine in subsequent examinations which had been attacked. Often adult sawflies emerged before the cocoons were attacked, and these adults were frequently eaten. In nature, living sawfly adults would not normally be available in the litter except while emerging from the cocoons. The other types of food provided were small cubes cut from potatoes, and pieces of decaying twigs found in the litter. The containers were examined periodically and fresh food was added. The rate of food consumption proved to be low and nearly always more food of each type was provided than was eaten. Thus food consumption during the rearings was rarely limited by availability. At each examination notes were taken on the amount of food eaten, and on the condition and size of the larva. When potatoes were fed upon, the larva usually made a tunnel about the width of its own body, and the amount eaten could be estimated in terms of 'potato units', where a unit was a quantity of potato equal in size to the body of the larva.

It was planned to carry out examinations at intervals of two weeks. Throughout the period of the rearings, however, the writer was engaged in field work on other projects, and in some instances the intervals between examinations were a month or longer. Since it is important to maintain proper moisture conditions in the containers by wetting the litter from time to time, mortality was therefore high. Although 280 individual rearings were started, only 190 were conducted over a sufficiently long period to provide worthwhile information on food habits. The other larvae either pupated without feeding or died soon after rearing was started.

In summarizing the results for each larva, the number of months was determined during which it lived and had food of each type available. The number of months was then totalled for all larvae of a given species, the corresponding food consumption was totalled, and the results were expressed as the amount of food eaten per larva-month. (Table IV). There is no column for decaying wood in Table IV; although larvae sometimes entered a hollow, decaying twig to moult or pupate, no definite feeding on this material was recorded for any species.

Specimens of all species except *Ctenicera* sp. (No. 9) were reared, although some of the less common species were represented by a single specimen. All these species were found to attack and destroy sawfly cocoons (Table IV). Sawfly adults were also eaten by all species to which they were available, and the same is true of potatoes. The presence or absence of potatoes had no apparent effect on the habit of attacking sawfly cocoons. The rate of consumption of these foods was found to be low, the average larva eating only 0.28 cocoons in one month, or roughly one cocoon in four months. (When a cocoon was entered or an adult attacked, all but the heavily sclerotized parts of the insect was devoured; decimal values result from arithmetic division rather than from partial consumption of an individual). Because of the small number of specimens representing each species, it is doubtful whether the differences in food consumption among species are significant. Variability was very high, even among individuals of the same species. Of the 190 larvae, 20 per cent accepted none of the food provided, although reared for periods as long as 15 months.

In determining food preferences, consideration must be limited to those individuals to which all types of food were available simultaneously. For example, of all the larvae which had insect food (cocoons or adults) and plant food (potatoes), 8 per cent accepted only the former, 64 per cent accepted both, and 28 per cent accepted only the latter. This is not significantly different from the 25:50:25 distribution which would be expected in the absence of any preference between insect and plant food. For sawfly cocoons and sawfly adults, the corresponding percentages were respectively 25:47:28, and here again no preference can be demonstrated.

When the same test was carried out for 68 specimens that were provided with both living and dead sawfly cocoons, it was found that 51 per cent fed upon living cocoons, 22 per cent upon both, and 27 per cent upon dead cocoons. By

TABLE IV.

Results of Individual Rearings to determine Food Habits of Larval Elateridae. (A dash indicates that the food in question was not supplied. A potato unit is a quantity of potato equal in size to the body of the larva.)

Species	Number reared	Mean length (mm.)	Total larva-months	Food eaten per larva-month		
				Sawfly cocoons	Sawfly adults	Potato units
C. triundulata	44	10.7	210.1	0.21	0.13	0.33
C. nitidula	43	14.3	233.5	0.31	0.39	1.03
C. r. aeraria	16	18.9	105.0	0.47	0.20	0.69
C. sp. (No. 11)	14	12.4	109.0	0.05	0.33	0.72
C. rufopleuralis (?)	10	22.2	46.2	0.09	0.13	0.17
C. p. propola	3	11.5	22.0	0.32	—	—
C. appropinquans (?)	7	22.6	63.0	0.52	—	—
C. appressa	4	15.0	21.5	0.19	0.40	0.88
C. hieroglyphica	4	16.0	15.0	0.60	0.40	2.12
C. mediana	2	18.5	18.0	0.17	—	—
C. sp. (No. 20)	2	12.0	7.0	0.14	—	1.33
A. limosus	10	18.1	27.5	0.29	0.32	0.56
D. vagus (?)	1	10.0	7.0	0.29	—	—
Ampedus spp.	7	16.4	25.5	0.59	0.25	0.21
A. rufifrons	1	23.0	8.0	0.38	—	—
S. honestus	1	30.0	1.0	2.00	—	—
E. decoratus	21	16.0	52.0	0.12	—	—
All species	190	14.8	971.3	0.28	0.24	0.62

applying the chi-square test it can be demonstrated that this represents a significant preference for living cocoons. The dead cocoons used in these tests had been dead for some time and there was no doubt as to their condition. Without dissection, however, it can never be determined with certainty whether cocoons that are thought to contain a living stage of the sawfly are not actually dead or parasitized. When it was necessary to leave the containers for several weeks without replacing the food, it is probable that many of the so-called living cocoons died before the end of the period. Accordingly, the only conclusion to be reached is that there is a preference for living or recently dead cocoons as compared with old dead cocoons. On fresh, hard-walled cocoons that had not been softened by moisture, evidences of unsuccessful attack, in which the wireworm failed to penetrate the wall of the cocoon, were sometimes noticed. Empty cocoons from which the sawfly adult had emerged, cutting off the end, were attacked only very rarely. This shows that the contents of the cocoon rather than the cocoon wall provide the incentive which causes the larva to chew its entrance hole.

Other feeding records noticed in the course of field collecting included the presence of larval Elateridae in spruce cones on the ground, where they appeared to be feeding upon the seeds. The most unusual record obtained was the presence of a larva of *Ampedus* sp. on the body of a trapped red-backed vole, *Clethrionomys gapperi ochraceus* (Miller), where it was feeding at a small wound.

Schaerffenberg (7) carried out similar studies on elaterid larvae found in pine forest litter in Germany in order to find which species were feeding upon pupae of *Bupalus piniarius* (L.). He concluded that the majority of the species were predominantly saprophagous, roots and insects being a secondary food. Pupae of *B. piniarius* were readily eaten but formed an important item of diet only when abundant. In the present study there was no noticeable feeding on the pieces of decaying wood that were provided. It is quite possible, however, that smaller particles of humus were eaten, as time was not available for the close observation necessary to detect such feeding.

Degree of Control

For any factor affecting the cocoon stage of *Gilpinia hercyniae*, it is very difficult to determine the degree of control in terms of the number or percentage of cocoons destroyed in each generation. The cocoons are very durable, and each collection contained cocoons that had accumulated for several years and could not be separated as to age. In New Brunswick the sawfly has two overlapping generations each season, and as a further complication, a proportion of the cocoons remains in diapause for one or more years. The only measure of the control effected by larval Elateridae, therefore, is the percentage of cocoons having wireworm entrance holes, based on collections which represent the accumulation from several generations of the sawfly.

Extensive collections of cocoons were made throughout the years of the sawfly infestation by the staff of the Fredericton Laboratory. The cocoons in each collection were classified as follows: Sound, Emerged, Killed by Mammals, Killed by Insects, Dead but Intact. The category 'Killed by Insects' included all cocoons with small holes, resulting from wireworm attack, parasite emergence, and other factors. The nature of the entrance holes made by wireworms was studied with some care, using cocoons that had been attacked in the rearing cages. The hole is round to slightly elliptical in shape and its diameter varies with the body diameter of the larva. It may occur anywhere on the cocoon, but is generally on the side rather than on the end. Occasionally, after consuming the contents of the cocoon, the larva chews an exit hole on the

opposite side. As a general rule, however, it enters only part way into the cocoon and backs out of the same hole. Since the body of the larva is somewhat distended after feeding, this forces the edge of the hole outwards and leaves a slight rim. This rim has considerable diagnostic value, especially for freshly attacked cocoons. After repeated soaking and drying in the field, however, it tends to disappear. Samples of 'Killed by Insects' cocoons collected on all plots in different years were saved until the study was completed, and several thousand of them were then subjected to a critical examination. Of these cocoons, 6.8 per cent showed definite evidence of wireworm attack, as revealed by the presence of the rim; 56.5 per cent had definitely been killed by other factors; and the other 36.7 per cent could be classified as possibly killed by wireworms, but too old at the time of collection for more definite diagnosis. If it is assumed that one-half of the cocoons in the last category were entered by wireworms, and add to this the cocoons in the first category, then approximately 25 per cent of the cocoons classified as 'Killed by Insects' were killed by wireworms. This estimate is somewhat arbitrary, but is the best that can be made under the circumstances.

In preparing Table V the factor 0.25 has been applied to the percentages of cocoons classified as 'Killed by Insects'. The results represent the percentages of all collected cocoons that are considered to have been entered by larval Elateridae. Records for cocoons collected after 1941 have not been used because the outbreak had declined by that date and few new cocoons were being added to the population in the litter. For purposes of comparison, the percentage of cocoons destroyed by small mammals is also shown. It is apparent from Table V that larval Elateridae played only a minor role in the natural control of *G. hercyniae*, a balanced mean for all collections showing that only 2.3 per cent of the cocoons were entered by elaterid larvae. Probably a proportion of these cocoons were dead at the time of attack, leaving an actual control of between one and two per cent. This low percentage is understandable in view of the heterophagous habits of the larval Elateridae; their low rate of food consumption; and their low populations, which showed no response to increasing sawfly populations.

Comparisons are possible between the number of cocoons destroyed in the field and the food capacity as indicated by individual rearings. During the years of active infestation at Acadia Station, the mean annual increase in the number of cocoons showing wireworm attack was 0.27 cocoons per square foot. With a mean wireworm population of 0.47 per square foot (Table III) and a food capacity of 0.28 cocoons per month (Table IV), this degree of control could be effected by the existing population in about $0.27 \div (0.47 \times 0.28) = 2$ months. The mean increment in cocoons destroyed at Young's Brook was 0.57 per square foot per year, and by the same calculation this represents 8 months' food for the wireworm population. For Brandy Brook the increment of 0.62 cocoons represents 2-3 months' food. Since a wide variety of food is available in the natural habitat, including the cocoons, puparia, and larvae of other insect species, it would be expected that the consumption of *G. hercyniae* cocoons would be lower than that indicated by rearing experiments.

Associated Insects

Population records were not kept for other insect species inhabiting the litter layer in association with larval Elateridae. These other species included several Lepidoptera, Hymenoptera, and Diptera, which feed above the ground but pupate in the litter, as well as some species which obtain their food in the litter. These latter species were relatively uncommon in relation to larval

TABLE V.

Percentage of Sawfly Cocoons destroyed by Larval Elateridae on Various Plots, in relation to the Percentage destroyed by Small Mammals.

	Acadia Station, N.B.	Young's Brook, N.B.	Other plots, N.B.	Brandy Brook, Gaspé	Other plots, Gaspé
Collection period	1938-41, inc.	1937-41, inc.	1934-41, inc.	1937-41, inc.	1932-37, inc.
No. of cocoons examined	10,000	42,600	29,400	96,300	102,800
Per cent of cocoons destroyed by small mammals	21.9	23.6	11.2	46.0	39.0
Per cent of cocoons destroyed by larval Elateridae	6.8	2.1	2.4	2.4	1.8

Elateridae, but a number of them were reared to determine whether they would attack *G. hercyniae* cocoons. Brief notes on these insects follow:—

Hepialus gracilis Grt. (Lepidoptera: Hepialidae). Large larvae of this species were taken on all plots but were not numerous. Five were provided with sawfly cocoons and reared to the adult stage. A single sawfly cocoon was attacked and most of the cocoon wall was eaten in addition to the contents. It is uncertain, therefore, whether this species is normally predatory.

Isomira sp. (Coleoptera: Alleculidae). Larvae of this species were next in abundance to larval Elateridae and were probably about one-tenth as numerous. Several specimens were reared but did not attack sawfly cocoons.

Byrrhus americanus Lec. (Coleoptera: Byrrhidae). Adult 'pill-beetles' were found rather commonly, but not the larvae. Some adults were caged but did not attack cocoons.

Coleoptera: Carabidae. Several species of ground beetles were collected in both the larval and adult stages. The larvae did not attack cocoons but the adults attacked both cocoons and emerged sawfly adults. Large ragged holes were left in the cocoons, more similar to the openings made by small mammals than to those made by wireworms.

Coleoptera: Staphylinidae. This family was relatively uncommon. Three adults were caged and one made an entrance into a soft, dead cocoon.

Diptera: Tipulidae and Tabanidae. Larvae of both families were collected from spruce litter but no attacks on cocoons were recorded for caged specimens, probably because of the unsuitable mouth-parts.

Bibio nervosus Lw. (Diptera: Bibionidae). Maggots of this species were fairly common in the litter in some years, and in captivity they fed upon potato cubes but not upon sawfly cocoons or adults.

Summary and Conclusions

1. To find the role of larval Elateridae in the natural control of the European spruce sawfly, *Gilpinia hercyniae* (Htg.), investigations were conducted in New Brunswick and Gaspé between 1939 and 1946.

2. Some twenty species of larval Elateridae were collected from the litter layer under spruce trees. These species are listed and a key presented for their identification.

3. Nearly 90 per cent of the larvae collected in New Brunswick belonged to the genus *Ctenicera*, and 55 per cent to the two species *C. triundulata* (Rand.) and *C. nitidula* (Lec.). The other common genera were *Agriotes*, *Dalopius*, and *Ampedus*. The Gaspé population consisted largely of *Eanus decoratus* (Mann.) and it is believed that this difference in species composition resulted largely from the deep moss layer of the collection area in Gaspé.

4. A similar species composition for New Brunswick prevailed for adult Elateridae collected from spruce foliage throughout the Province, with the exception that additional species from nearby cultivated land were collected from foliage.

5. Populations of larval Elateridae, as measured over a period of years, varied from 0.24 per square foot to 1.04 per square foot on different permanent plots. Deep litter layers appeared to harbour higher populations than did shallow ones. Population changes from year to year showed no relation to the population trend for sawfly cocoons, as measured on the same plots.

6. Food habits were studied by means of individual rearings. All species fed upon sawfly cocoons, emerged sawfly adults, and plant food as represented by potato tubers. Decaying twigs in the litter were not eaten but were often used as a shelter for moulting and pupation. Whether smaller particles of humus were eaten was not observed. The rate of food consumption was low; for the average larva, one cocoon was eaten every four months. There was no significant food preference as between cocoons and potatoes, or between cocoons and sawfly adults. Living or newly dead cocoons were preferred to those which had been dead for some time. These studies did not reveal any specific differences in food habits and it is concluded that, for ecological purposes, all members of the family inhabiting spruce litter may be treated as a single group.

7. In comparison with small mammal predators, larval Elateridae played only a minor role in the complex of control factors affecting the cocoon stage of *G. hercyniae*. The analysis of extensive cocoon collections from New Brunswick and Gaspé during the outbreak showed that only 1 to 2 per cent were destroyed by larval Elateridae.

8. Several species of insects that were associated in the litter with larval Elateridae are also discussed. Of these, only adult Carabidae readily attacked sawfly cocoons.

Acknowledgments

This investigation constituted one aspect of a broader project on the natural control of the European spruce sawfly, which was conducted under the direction of R. E. Balch, Officer-in-Charge, Dominion Entomological Laboratory, Fredericton, N.B. All officers of that Laboratory participated in the sawfly cocoon sampling, and, at the writer's request, were kind enough to collect and record larval Elateridae from the same samplings quadrats. W. A. Reeks has made available certain records of the Forest Insect Survey as well as data from the Young's Brook area. Without the generous assistance of Robert Glen, who was then stationed at the Dominion Entomological Laboratory, Saskatoon, Saskatchewan, many of the species of larvae could not have been identified. To W. J. Brown of the Division of Entomology, Ottawa, the writer is indebted for the identification of reared adults.

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A Reflex Photocopying Box for Books[1]

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There are many types of commercial photo copying machines designed to make paper negatives or direct paper positives without the aid of a camera. These range from the costly rotary printers used in industry to the cylindrical type used in offices. Most of these produce excellent copies of single sheets; but with many of them there is considerable difficulty in making copies from books, the printing usually being blurred and the copy unevenly shaded. The physical pressure required to make perfect contact during exposure often damages larger books.

A simple machine has been designed by the writer to accommodate books for photocopying, and is especially useful in the reproduction of charts and diagrams. The machine consists essentially of a wooden box 22 in. long, 11 in. high, 13 in. wide, and fitted with a heavy solid lid. Heavy plywood is used on all sides except the front, where quarter-inch plywood is used. The lid is made of two pieces of plywood three-quarters of an inch thick and glued together. The underside of the lid is lined with heavy felt (Fig. 1, d); the lower back edge is bevelled, and the lid has a pull handle (Fig. 2, c).

Light is obtained from a 60-watt show-case lamp, 18 in. long, placed at the bottom of the box. The light brackets, holding each end of the bulb, may be moved horizontally from the outside, by lock-bolts (Fig. 1, a). The bulb can be replaced through holes, covered by masonite, one on each side of the box (Fig. 1, b). Five inches from the bulb is a piece of frosted glass which may be covered with an amber cellophane blind fastened at one end of the box. A thin strip of wood reinforces the free end of the blind, and draw strings are tied to each corner. The strings are continued through small holes in the opposite end of the box (Fig. 2, e). Set in the top, protruding one-eighth of an inch above the surface of the box and flush with the front edge is a 10-in. by 12-in. piece of plate glass (Fig. 1, c). Two "L" flanges are screwed to the back of the box for clamping it to the bench (Fig. 3, a). A light switch is mounted on the front panel near the entrance of the light cord (Fig. 2, d). Spring catches and hinges are placed at the front and rear as shown in Fig. 2, a and b; a detailed sketch of each is given in Figs. 3 and 4.

The hinge assembly, at the rear of the box, has several components. One part consists of two pieces of steel rod three-eights of an inch in diameter, brazed together in the form of a T. A brass supporting piece is placed around the joint and soldered (Fig. 3, b). The stem (Fig. 3, c) is inserted into a six-inch brass sleeve in the lid at the back (Fig. 3, d), the T thus being on its side. The upper part of the T is threaded and left free, whereas the lower is caught in two

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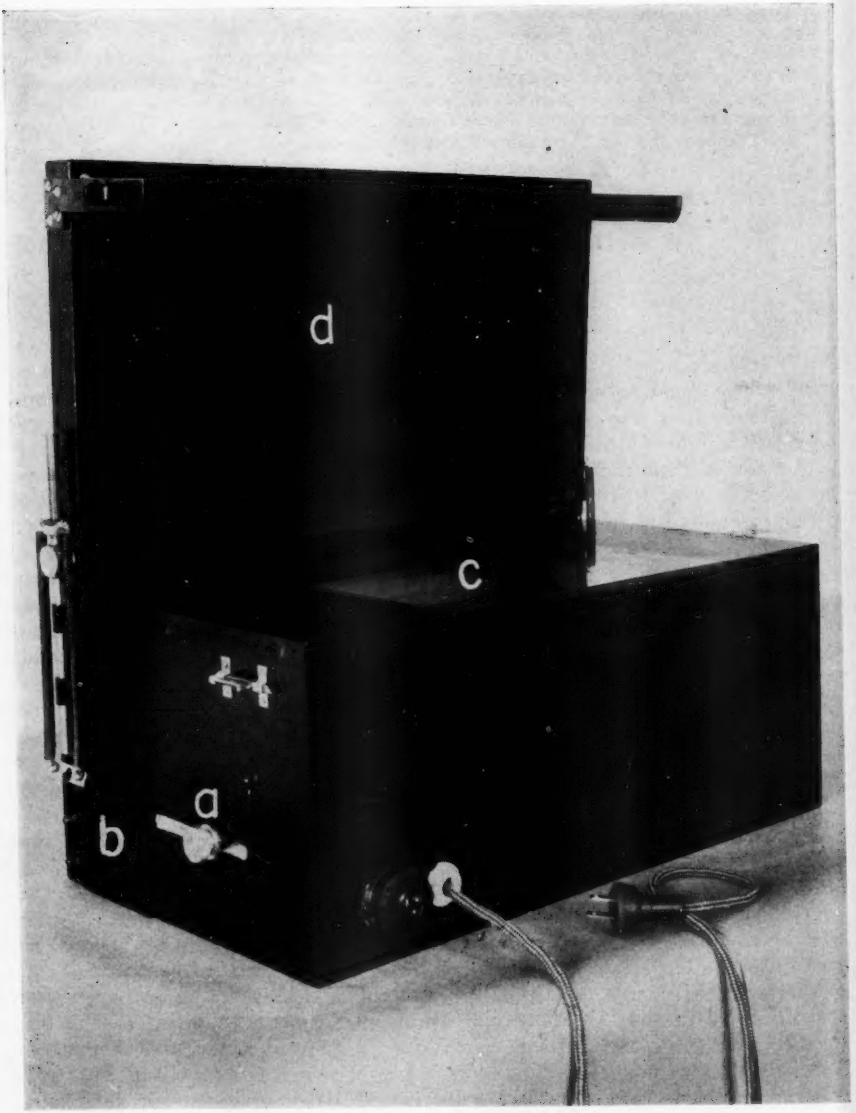

Fig. 1. Front view of box with the lid at rest.

brass guides screwed to the sides of the box (Fig. 3, e and j). A nut is threaded well down on the upper, protruding piece, over which is placed a metal strip 1½ in. long and five-eighths of an inch wide (Fig. 3, k). Hooked to each end of this metal strip is a medium-weight screen-door spring eight inches long (Fig. 3, f). The lower ends of the springs are held apart by a similar piece of metal fastened to the bottom of the box (Fig. 3, g).

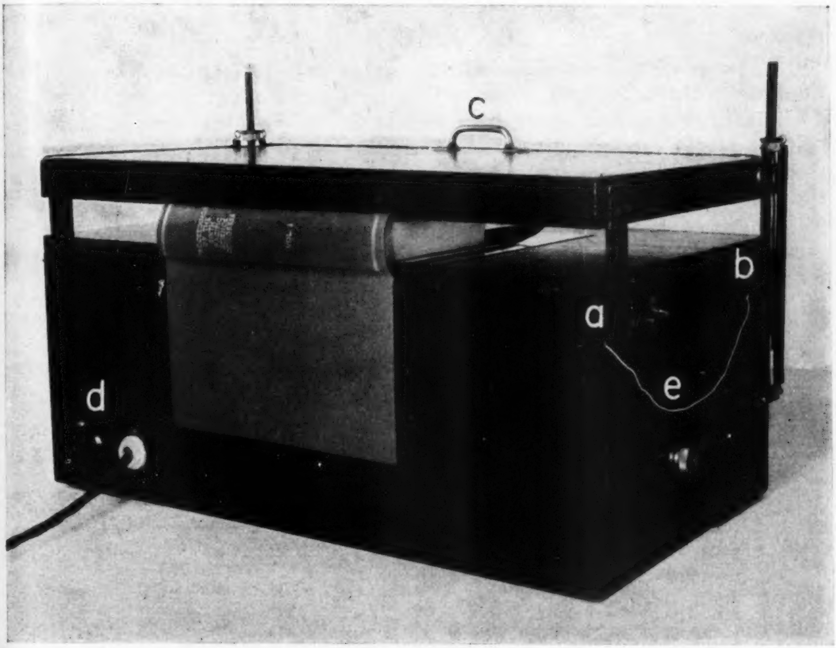

FIG. 2. Front view of box, showing a book ready for exposure.

Each ratchet clamp contains two separate parts. The upper one, attached to the lid (Fig. 4, a), is of heavy strip steel, the inner edge of which is toothed (at least ten teeth to the inch) (Fig. 4, b). A trigger grip for raising the lid is brazed on (Fig. 4, c). The lower part, a spring catch, is secured to the box by two metal flanges (Fig. 4, d and h), which are fastened by screws. A square rod (Fig. 4, e), slides beneath the flanges and is tapered at the front end so that it may slip into the teeth of the upper part (Fig. 4, f). Brazed to the square rod just behind the front flange is a metal support (Fig. 4, k). Extending back from this rod is a similar piece (Fig. 4, i), on which is placed a coiled spring (Fig. 4, g). The rod has a supporting collar fastened to the back flange (Fig. 4, j), against which the spring rests.

To use the box for copying, the spring tension is regulated by adjusting the nut shown in Fig. 3, h (this need be done only once, when the box is first set in operation). Reflex paper is placed face-down on the surface of the page with a sheet of black paper behind it. The book is then turned over with the back of the reflex paper next to the plate glass, so that the free part of the book hangs over the edge. With one hand pressing the book toward the box, the lid is brought down and secured. The hinge and catch assembly hold the book as shown in Fig. 2, and automatically compensate for any thickness of book. When large publications are being copied, the handle (Fig. 2, c) is used to raise the lid. The light bulb is then brought parallel with the centre of the book by manipulating the lock-bolts. If the publication is old, faded, or discoloured, the cellophane sheet is pulled across the frosted glass before the exposure is made. To release the lid, the thumb is placed against the metal rod at k (Fig. 4) and, with

the index finger placed under the trigger piece, the lid is raised to the upright position.

The exposure time is approximately six seconds but must be increased four times when the cellophane is used. When the reflex paper is being developed, a faint grey tone appears in the light areas at the end of thirty seconds, indicating that the proper exposure time has been used. The developed reflex paper is put through the usual fixing and drying procedures, as in ordinary contact printing, and then used as a negative to print any number of copies.

The usual dark-room facilities are not necessary for handling reflex copying paper. Most sensitized materials used in this type of work may be opened in subdued incandescent light for short periods.

When a single sheet is being copied or when the box is being used as a

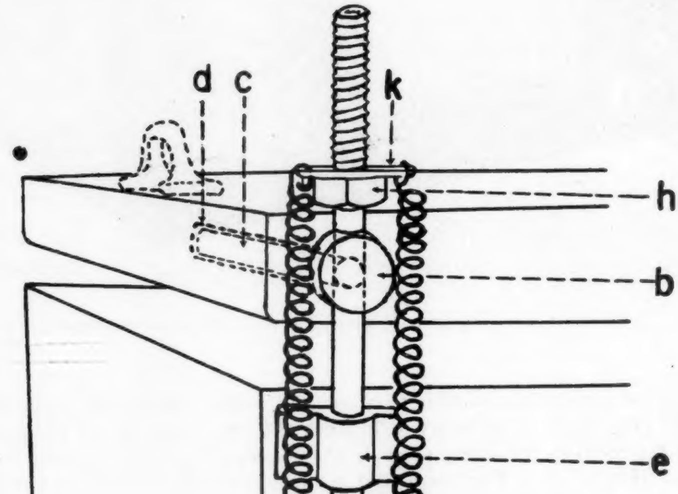

FIG. 3. Hinge assembly as mounted on the box.

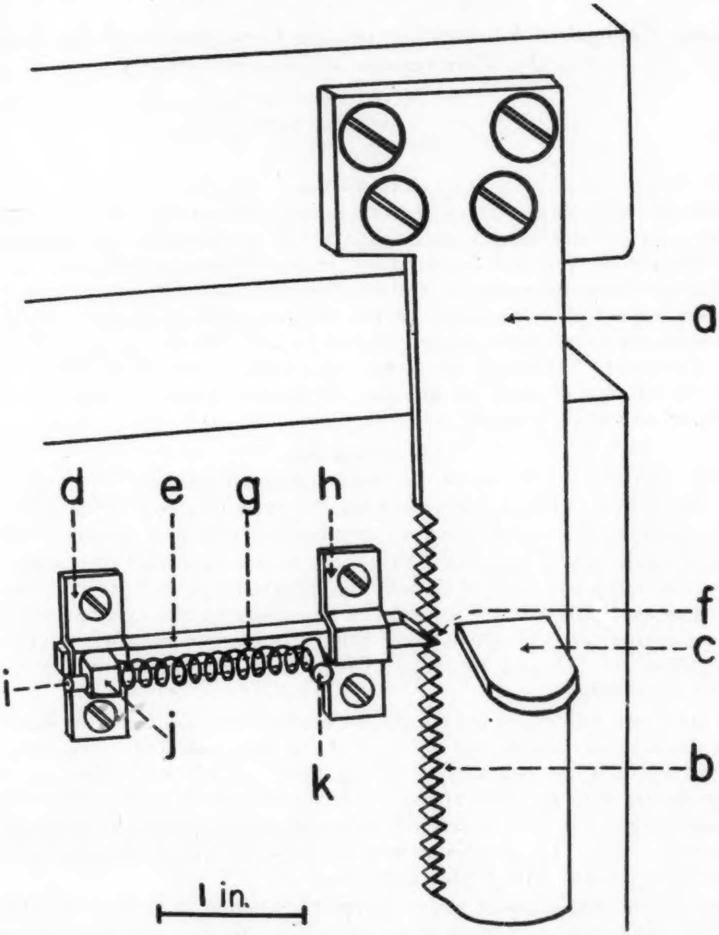

FIG. 4. Ratchet clamp showing ratchet in place.

contact printer, the spring catch is arrested by winding an elastic band around points j and k (Fig. 4). Perfect contact is assured by the weight of the lid, thus eliminating time spent to manipulate the catch.

One of the main features of the box is the automatically adjustable lid which holds the book in place when the exposure is made. At all times, uniform pressure is assured, whether the material consists of a single sheet or a number of pages up to two inches in thickness. The prints are sharp, clear, uniform in tone, and often decidedly better than the original. The speed and ease with which this box may be operated enables even a novice to expose a page in less time than it takes to develop it and with no harm to the publication. Although the copies may not take the place of microfilm, they have the distinct advantage of being facsimiles of the same size and may be used without the necessity of purchasing expensive camera and projection equipment.

Grateful acknowledgment is made to Mr. R. C. Hewson of the Belleville laboratory for advice and assistance in the construction of the box.

Some Ecological Factors Governing Populations of the Larch Sawfly, *Pristiphora erichsonii* (Htg.)[1]

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Introduction

Several ecological factors governing populations of the larch sawfly, *Pristiphora erichsonii* (Htg.), have been studied in Manitoba and Saskatchewan since the present outbreak began about 1939. It soon became clear that soil moisture, parasites and predators, and the growth habits of tamarack were among the most important components of the environmental resistance. Data from observations and experiments were gathered by several investigators of the Forest Insect Laboratory, Winnipeg, Manitoba, and are still largely unpublished. In this paper, an attempt is made to appraise the over-all effect of these factors on abundance of the larch sawfly.

Soil Moisture

Soil moisture appears to be the most important physical factor governing sawfly abundance. This is understandable, for in the Prairie Provinces the insect inhabits swamps and spends about 10 months each year in a cocoon in the soil.

In an early article (Lejeune, 1947a), the author suggested that water levels in tamarack stands had much to do with the abundance of the insect. Subsequent work (Lejeune and Filuk, 1947b) showed that under certain experimental conditions cocoons of the larch sawfly were killed by excessive moisture. More recent investigations by Fell and Burbidge (1949) have done much to clarify these moisture relationships.

Their work shows that the effects of excessive soil moisture differ depending on the duration of flooding and the stage of the insect affected. Dormant, overwintered cocoons do not survive spring flood periods exceeding six weeks. During shorter periods, many cocoons may die but the mortality curve for sublethal submergence periods is irregular and evidently not proportional to the time spent under water. The development of cocoons that survive flooding is delayed but no other adverse effects have been observed.

Sawflies in post-diapause stages within the cocoon at time of flooding are killed by immersion periods of from three days to two and one-half weeks, depending on the stage of development. Insects in advanced stages are killed more quickly. The greatest number of post-diapause stages occur about mid-June in a normal season in Saskatchewan and Manitoba.

Larvae in newly-spun cocoons are susceptible to moisture. Few cocoons under two weeks of age can survive flood periods of two weeks or longer. However, as cocoons age they gradually become resistant to moisture. This resistance attains a constant level in cocoons eight to ten weeks old. Under field conditions this level is reached about the end of September. It is assumed that at this time resistance of cocoons to moisture corresponds with that found in dormant cocoons in the spring.

From results outlined, it is evident that under certain conditions high water levels in tamarack stands can drastically reduce larch sawfly populations or delay emergence of the adults. On the other hand, it is not known how natural enemies of the larch sawfly, the host tree, or associated tree species react to flooding. Where moisture conditions achieve complete control, the host stand probably

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benefits in the long run. However, where the larch sawfly is only partially controlled by moisture, parasites and predators may react unfavourably to environmental changes caused by flooding.

Parasites, Predators and Disease

Parasites

Biological control by insect parasites has been studied intensively since the current outbreak began. Investigations were encouraged by the remarkable success apparently achieved by the introduction of the ichneumon, *Mesoleius aulicus* (Grav.), in earlier outbreaks (Criddle 1928, Graham 1931, Hewitt 1912, Hoping et al. 1943). Studies have sought to determine: (1) the incidence and distribution of insect parasites, (2) the factors governing the effectiveness of *M. aulicus*, (3) the effect of new releases of *M. aulicus*, and (4) the success of attempts to introduce other species of parasites.

The parasite complex of the larch sawfly in Manitoba and Saskatchewan is limited to two main species, *M. aulicus* and *Bessa harveyi* (T.T.). *M. aulicus* is almost certainly introduced but the status of *B. harveyi* is confused. Apparently identical forms of *B. harveyi* occur in Europe and North America (Hawboldt, 1947); the origin of the present parasites on the larch sawfly in Western Canada is not known. There is some presumptive evidence, which is by no means conclusive, that present populations may have arisen from introduced stock. It has been impossible to verify this hypothesis from the meagre records on the species in Western Canada prior to the current outbreak.

Mesoleius aulicus occurs in Saskatchewan and Manitoba wherever the larch sawfly is found. It is most abundant in northern Saskatchewan and in Riding Mountain Park, Manitoba. However, effective parasitism (where the parasite kills the host) has rarely exceeded 5 per cent in areas sampled since 1939. The number of host larvae parasitized is often high, occasionally reaching 60 to 70 per cent, but generally only a small proportion of the parasite eggs hatch to produce larvae capable of killing the host. Recent data covering several areas in Saskatchewan and Manitoba show that the number of parasite eggs which hatched ranged from 7.5 to 20 per cent in 1948 and 10 to 90 per cent in 1949.

Unpublished results obtained by J. A. Muldrew, Forest Insect Laboratory, Winnipeg, indicate that the larch sawfly has developed a natural immunity which prevents the eggs of the parasite from hatching. The host larva appears to accomplish this by forming a capsule around the parasite egg shortly after it is laid in the host. Moreover, it seems that *M. aulicus* parasites being introduced from British Columbia, where the species is much more effective, will be subjected to the same resistance factor in Manitoba and Saskatchewan as the local stock.

Bessa harveyi shows more promise than *M. aulicus* does. In the early years of the outbreak, 1939 to 1945, *B. harveyi* was either scarce or absent. Since 1945 it has increased steadily in the older declining infestations in western, central, and eastern Manitoba. In these areas it now exerts a much greater measure of control than does *M. aulicus*. Cocoon dissections show that at times more than 45 per cent of the sawfly larvae contain maggots of the parasite.

In areas of Saskatchewan more recently attacked by the larch sawfly, the parasite is being recovered in small but steadily increasing numbers.

It is believed that in the past the incidence of *Bessa harveyi* may have been underestimated. Estimates of parasitism were based on the occurrence of maggots in hibernating cocoons of the larch sawfly. However, this did not take into account the maggots which evidently leave host cocoons in late summer and overwinter as puparia in the soil, and some first-generation adults which

emerged during the summer. Therefore improved methods of sampling would probably show an even higher incidence of *B. harveyi* than has been indicated by methods used to date.

Other species, *Tritneptis klugii* (Ratz.) and *Aptesis basizonia* (Grav.), supplied by the Dominion Parasite Laboratory, Belleville, Ontario, were released in 1949 and 1950. *T. klugii* occurred in the Prairie Region at one time but it has not been recovered during the present outbreak. Its habits suggest that it may have difficulty in surviving when the density of the host is at a low level. Consequently it may have disappeared from the parasite complex between outbreaks. If this is true, it is hoped that recent releases may help to re-establish the species. Several years may elapse before conclusive evidence can be obtained on the success of these liberations.

Predators

Predators of the larch sawfly include mice and shrews, insects, and birds. Mice and shrews, which feed on cocoons in the ground, have almost exterminated the sawfly population in some stands. Where the nesting of small mammals is favoured in suitable, well-drained swamps, the number of cocoons destroyed in sections of Manitoba has ranged from 10 to 60 per cent (Lejeune, 1947a). In areas sampled from 1939 to 1945, the cocoons destroyed averaged 37 per cent. Although probably little can be done to increase the number of mice and shrews, it is important to realize that sawfly infestations would be much more severe in their absence. Wireworm larvae also destroy a small number of cocoons. Nymphs of a stink bug, *Podisus* sp., have been observed feeding on eggs and larvae of the larch sawfly and their value as predators may be greater than is suspected. No evidence of extensive destruction of sawfly larvae by birds has been obtained.

Disease

Diseases of the larch sawfly are being investigated at the Laboratory of Insect Pathology and the Forest Insect Laboratory in Sault Ste. Marie. There is no evidence as yet of a virus disease in the larch sawfly. A considerable number of species of bacteria have been isolated from dead sawflies collected in the field and their significance is under investigation. Representatives of several genera of fungi have also been recovered from dead larvae and pupae. Under laboratory conditions high mortality of the larch sawfly can be induced by certain fungi but attempts to establish epidemics in the field have not been encouraging to date and emphasize the need for more fundamental studies of the physiology of fungi and the parasite-host relationship[3].

Tree-Growth Characteristics

The growth habits of tamarack tend to prevent the maintenance of severe infestation levels in a given stand for more than three or four consecutive years. Severe attacks by the larch sawfly usually bring about the following reactions:

1. The amount of foliage produced by the trees in successive years of attack declines rapidly. After three to four consecutive years of severe infestation, trees produce so little foliage that relatively few larvae can be supported.
2. Simultaneously the number and length of terminal shoots decrease. Because sawfly adults lay their eggs only on new shoots, populations cannot be maintained in their absence.

As the vigour of the trees is reduced, these two phenomena operating together usually cause the sawfly population to decline rapidly. Consequently

[3]Personal communication–Laboratory of Insect Pathology, December 7, 1950.

severe infestation of three to four years' duration may be less damaging in the long run than a prolonged attack of moderate intensity.

Interaction of Factors and Effect on Populations

As components of the environmental resistance the factors discussed fall into two main groups—physical and biotic. Moisture is obviously a physical factor and is density-independent. Parasites, predators, and disease are biotic factors and are density-dependent. The third factor, tree growth, is not so easily classified but as it operates mainly on a density-dependent basis, involving nutritional and competitional elements, it is considered a component of the biotic resistance.

Records accumulated from several infestations in Manitoba and Saskatchewan indicate that one, or a combination of two or more, of these factors may bring sawfly populations under control.

Abnormally high water levels in the spring of 1950 in several stands in eastern Manitoba decimated populations by preventing development of sawflies in cocoons. In these stands foliage and terminal shoots were not limiting factors. High parasitism by *B. harveyi* had exerted an appreciable measure of control in 1948 and 1949 but high water levels in 1950 were decisive in subduing the infestations. As a density-independent factor, excessive moisture requires no 'build-up' and under conditions that occurred in 1950, it can control infestations in a single season.

Bessa harveyi, aided by mice and shrews, is credited with bringing two infestations in Manitoba, one at Riverton and the other in Riding Mountain Park, under control. In the first location, moisture, foliage, and oviposition sites were not limiting factors. In the other, insufficient foliage and oviposition sites contributed to the population decline but it appears that *B. harveyi* ultimately was the decisive control agent.

There is no conclusive evidence that growth characteristics alone completely control infestations. However, they do contribute to the decline of larch-sawfly populations in two important ways. Firstly, by reducing the available food supply and oviposition sites, heavy populations may decline rapidly to the point where biological controls are able to gain the upper hand. Secondly, following the control of the infestation by parasites and predators, trees are in a weakened condition for several years and are able to prevent the sawfly population from increasing again.

In some instances growth characteristics appear to have held populations to sub-infestation levels where biological controls and moisture were unable to suppress the attack completely. Some stands that were attacked severely for several years have begun to recover and are producing foliage abundantly. The larch sawfly has not defoliated these stands extensively since recovery began. It must not be assumed from this, however, that growth characteristics are entirely responsible for this situation as parasites, predators, and moisture undoubtedly contribute to the continued suppression of these infestations.

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A Note on the Occurrence of *Catallagia dacenkoi* Ioff in North America, with the Description of a Nearctic Subspecies (Siphonaptera: Neopsyllidae)[1]

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As the flea fauna of mammals of northern North America becomes better known, its very close affinity with that of temperate and northern Asia becomes more apparent. Many of the genera are holarctic and are associated with holarctic genera of mammals. In a few instances, the fleas of the Old World and the New World are so similar in morphological details and host association that they are regarded as subspecies. For example, *Amphipsylla sibirica* (Wagner), *Malaraeus penicilliger* (Grube), *Megabothris calcarifer* (Wagner), and *Hoplopsyllus glacialis* (Taschenberg) have representatives in both the nearctic and the palaearctic regions. To this list must now be added *Catallagia dacenkoi* Ioff, a parasite of Microtinae; this species was described originally (Ioff, 1940, pp. 216-217) from the Altai Mountains of central Russia, and a new subspecies has now been discovered in northern Canada and Alaska.

Catallagia dacenkoi differs so markedly from the genotypical species, *C. charlottensis* (Baker), and other western nearctic species, that a separate genus might justly be proposed to contain it. The same may be said of *C. borealis* Ewing [= *C. onaga* Jordan], an eastern North American species, which also differs, and upsets a concept of the genus based upon *charlottensis* and its near allies[3]. Both *C. dacenkoi* and *C. borealis* fall into *Catallagia* only by lack of the genal comb, which is so characteristic of most genera of the Neopsyllidae. However, it should be remembered that this structure may have been lost independently by representatives of several genera, not necessarily closely related. Hence, "*Catallagia*" has become a repository for non-combed neopsyllids[4]; this grouping is a taxonomic convenience, perhaps, but apparently contains species representative of at least three lines of descent. The writer is now accumulating material with the intention of undertaking a more thorough analysis of the situation. For the present, *dacenkoi* and *borealis* will be allowed to remain in *Catallagia* Rothschild.

C. dacenkoi was described in Russian, with a German summary. Figures were provided of the clasper and sterna VIII and IX of the male, and of the spermatheca and sternum VII of the female. The type series consisted of two

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[3]Closely related to *C. charlottensis* (Baker) [= *C. motei* Hubbard] are: *C. decipiens* Rothschild [= *C. moneris* Jordan], *C. wymani* Fox, *C. sculleni* Hubbard [probable synonyms: *C. chamberlini* Hubbard, *C. vonbloekeri* Augustson, and *C. rutherfordi* Augustson], and *C. mathesoni* Jameson.

[4]*Delotelis* Jordan has already been erected to segregate a species formerly known as *Catallagia telegoni* (Rothschild).

males and nine females, collected from "*Evotomys rutilus*" [*Clethrionomys rutilus* Pallas] and "*Evotomys rufocanus*" [*Clethrionomys rufocanus* Sundevall] in the district of Katon-Karagai, in the Altai Mountains, Asia. The writer, through the kindness of Dr. Karl Jordan, F.R.S., examined, at Tring, a pair of this species from the Kondo Sosva Preserve, West Siberia, "ex Muridae", received from Dr. Ioff.

Nearctic representatives of this species show characteristics that warrant the erection of a new subspecies. Material is available from Alaska, northern British Columbia, the Mackenzie Delta, Wood Buffalo Park, and central Manitoba, where red-backed mice, *Clethrionomys* spp., and meadow voles, *Microtus* spp., appear to be the favoured hosts.

Catallagia dacenkoi fulleri new subspecies

Male

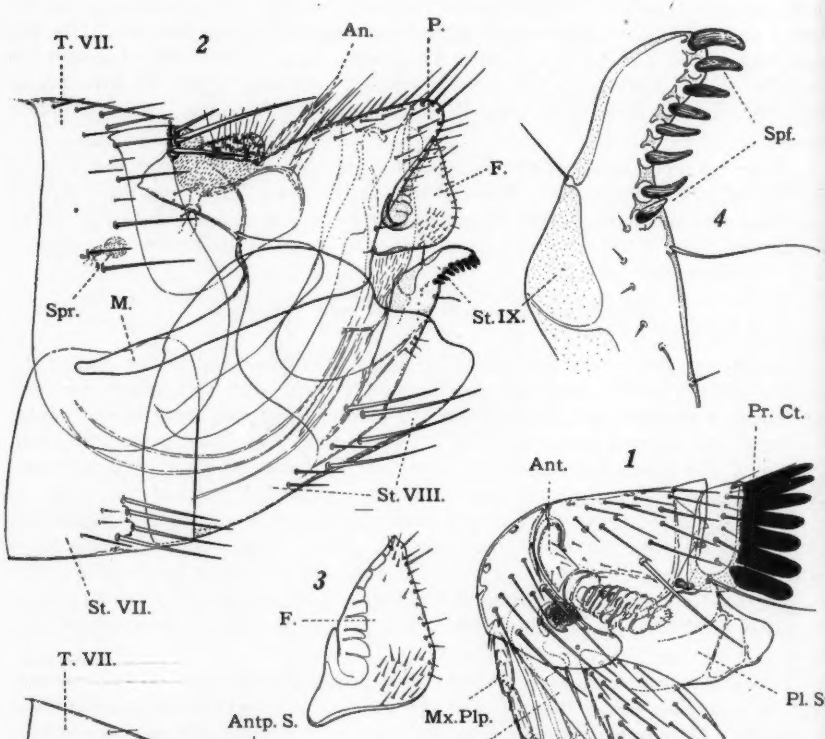
Ocular setae four; the first seta long, and set well forward of the eye, at the anterior margin of the antennal groove; beside it, a short seta which in some individuals is reduced to a slender hair. The remaining two setae of the ocular row long, and inserted below the eye at a point somewhat more posteriorly than is usual in the genus. Frontal row of about six subequal setae. Postantennal region with two oblique rows of setae in addition to the submarginal row (Fig. 1). A clypeal tubercle present. Eye relatively large and more deeply pigmented than in *charlottensis* and some other species. Labial palpus approximately two-thirds as long as the fore coxa. Thin setae along the margin of antennal segment II, approximately one-third as long as the club. Cervical sclerite (Jordan's "first vinculum") articulating in a small sinus on the dorsal margin of the pleurosternal plate.

Pronotal comb of about 14 (13-15) very heavy spines. One or two pseudo-setae on each side, under the collar of the mesonotum; metanotum lacking these structures. Metepimeral bristle-formula usually 3:4:1 or 4:4:1, occasionally 3:3:1 or 5:4:1.

Apical spinelets of abdominal terga as follows: I, 1 spine (rarely 2) per side; II, 2 spines (rarely 1); III, 1 spine (rarely 2); IV, 1 spine (rarely 0 or 2). Abdominal terga II to VII each with two rows of setae, the anterior row of about eight short setae, and the posterior row of about seven long setae, alternating with fine intercalary hairs. Stigma cavity of tergum VIII excessively large, exceeding that of the other species. Ostia of typical abdominal spiracles also unusually large.

Hind coxa with a row of spiniforms, and abdominal sternum II with lateral "striarium" as in many neopsyllids. Tarsal segments V of fore- and mid-legs with four lateral pairs of plantar bristles and a basal submedian pair; hind tarsi with just the four lateral pairs.

Clasper of the same general type as in *charlottensis* and the other western species, but with the movable process F very short and broad (Fig. 3), the proportions being approximately 45:25; in this character *C. d. fulleri* may be readily separated from *C. d. dacenkoi*, in which this structure is of more slender proportions, about 50:22. The point of articulation on F relatively low. Process P with marginal setae of which the apical six are two or three times as long as the remainder. F with sparse marginal setae, and a group of about 20 slender hairs, situated ventro-laterally. Manubrium of clasper straight, more or less parallel-sided, but tapering apically to a blunt point. Sternum IX very distinctive, bearing on the ventral surface of the posterior arm a closely set row of eight subequal, short, pigmented spiniforms. In addition to these a few slender setae as shown



Figs. 1-7. *Catallagia dacenkoi fulleri.* 1, Head and prothorax of male (holotype). 2, Abdominal segments VII, VIII, and genitalia of male. 3, Enlarged detail of movable process. 4, Enlarged detail of posterior arm of sternum IX. 5, Terminal abdominal segments of female (allotype). 6, Spermatheca, or receptaculum seminis. 7, Enlarged detail of anal stylet.

(Fig. 4). Sternum VIII equally distinctive, bearing on the posterior margin three short, broad, rounded lobes, separated by broad, rounded sinuses (Fig. 2). Ventrally, on each side of sternum VIII about seven setae, of which about four are long. Antepygidial setae three, of which the upper is about two-fifths and the lower one-half as long as the middle one.

Female

Details of chaetotaxy essentially similar to those of the male.

Second antennal segment with marginal setae nearly as long as the club; in this character differing from *charlottensis* and its close relatives, which have these setae short, as in the male.

Anal stylet about six times as long as broad (Fig. 7), much longer than in the other species; a long apical seta, with two minute hairs at its base. Spermatheca relatively small. The tail of this organ is apparently relatively longer in *C. d. fulleri* than in *C. d. dacenkoi*, according to Ioff's figure and the single female of the latter available for study. Sternum VII not deeply incised, but shaped much like that of *C. decipiens* Rothschild, with a broadly rounded lobe and a shallow sinus. About 16 setae per side on sternum VII, of which about seven are long and heavy (Fig. 5). The large stigma cavity of tergum VIII particularly noticeable, also the great size of the other spiracular openings. Three antepygidial setae as in the male, but the first and third proportionately somewhat longer.

Size (mounted specimens): ♂, average 2.5 mm. (2.45-2.55); ♀, average 2.75 mm. (2.55-3.0).

Holotype male and allotype female from Fort Smith, Northwest Territories, 25.X.47, ex *Clethrionomys gapperi athabascae* (Preble), collected by W. A. Fuller.

Paratypes, 7 ♂ ♂ and 15 ♀ ♀ as follows: Fort Smith, N.W.T., 17.X.47, ex *Clethrionomys g. athabascae*, 1 ♀ (W. A. F.); Fort Smith, 16.X.47, ex *Microtus pennsylvanicus drummondi* (Audubon and Bachman), 2 ♀ ♀ (W. A. F.); Fort Smith, 29.IV.48, ex *Clethrionomys g. athabascae*, 2 ♂ ♂, 2 ♀ ♀ (W. A. F.); Fort Smith, 8.V.49, ex *Microtus p. drummondi*, 1 ♂ (C. E. Law); Pikwitonei, Manitoba, V.49, ex *Clethrionomys gapperi* spp., 1 ♀ (J. B. Wallis); Atlin, British Columbia, 1933, ex *Microtus p. drummondi*, 1 ♀ (H. S. Swarth); Aklavik, N.W.T., 21.VIII. 48, ex *Microtus* spp., 2 ♀ ♀ (W. E. Stevens); Reindeer Station, Mackenzie Delta, N.W.T., 10-19.VIII.48, ex *Clethrionomys dawsoni dawsoni* (Merriam), 2 ♂ ♂, 5 ♀ ♀ (J. R. Vockeroth); Reindeer Station, 12.VIII.48, ex *Microtus* sp., 1 ♂, 1 ♀ (J. R. V.); Anchorage, Alaska, 1950, ex *Clethrionomys* sp., 1 ♂ (R. Rausch).

The writer has also examined, from Alaska, two females labelled: "Takotra, 11.VI.35", with no host data, and "Alaska, 26.VI.34, ex redbacked mice". These specimens were received through the courtesy of Major Robert Traub of the Army Medical Center, Washington, D.C.

The subspecies is named after Mr. W. A. Fuller, Mammalogist, Canadian Wildlife Service, Department of Resources and Development, Fort Smith, Northwest Territories.

The holotype and the allotype are No. 5720 in the Canadian National Collection at Ottawa. Paratypes will be deposited in the British Museum of

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Abbreviations Used in Illustrations

An.—anus; Ant.—antenna; Antp.S.—antepygidial seta; B.Cop.—bursa copulatrix; Cx—coxa; Ephy.—epipharynx; F.—movable process of clasper; Lb.Plp.—labial palp; M.—manubrium of clasper; Mx.—maxilla; Mx.Lc.—maxillary lacinia; Mx.Plp.—maxillary palp; P.—immovable process of clasper; Pl.St.—pleurosternal plate; Pyg.—sensilium; R.s.—spermatheca; Spf.—spiniforms; Spr.—spiracle; St.—abdominal sternum; Stig.—stigma cavity of tergum VIII; T.—abdominal tergum.

Natural History (Zoological Museum, Tring); the United States National Museum, Washington, D.C.; the Rocky Mountain Laboratory, Hamilton, Montana; and the collection of Major Robert Traub, Washington, D.C.

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Laboratory Course on the Electron Microscope

We are informed by the Acting Director of the Department of Engineering Physics in Cornell University that a summer laboratory course in Techniques and Applications of the Electron Microscope will be given this summer in the laboratory of Electron Microscopy in the Department of Engineering Physics from July 9 to July 21, 1951. This course is designed for those research workers, institutional and industrial, who have recently entered the field of electron microscopy or who are planning to undertake research problems involving applications of this instrument. Further inquiries should be addressed to Professor Benjamin M. Siegel, Department of Engineering Physics, Rockefeller Hall, Cornell University, Ithaca, New York.

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